Model-Based Design of a Battery-Electric Vehicle

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MIBRID

THEORY

Bond Graphs

Bond graphs are a way for engineers to generate detailed mathematical models of systems in an accessible, graphical way (Fig. 1). In a world where companies face higher expectations for safety and reliability, and rely increasingly on computer modelling and smart systems, it's vital that our models are correct. Bond graphs are perfect for exploring the complex systems and dynamic phenomena that the modern engineer faces.

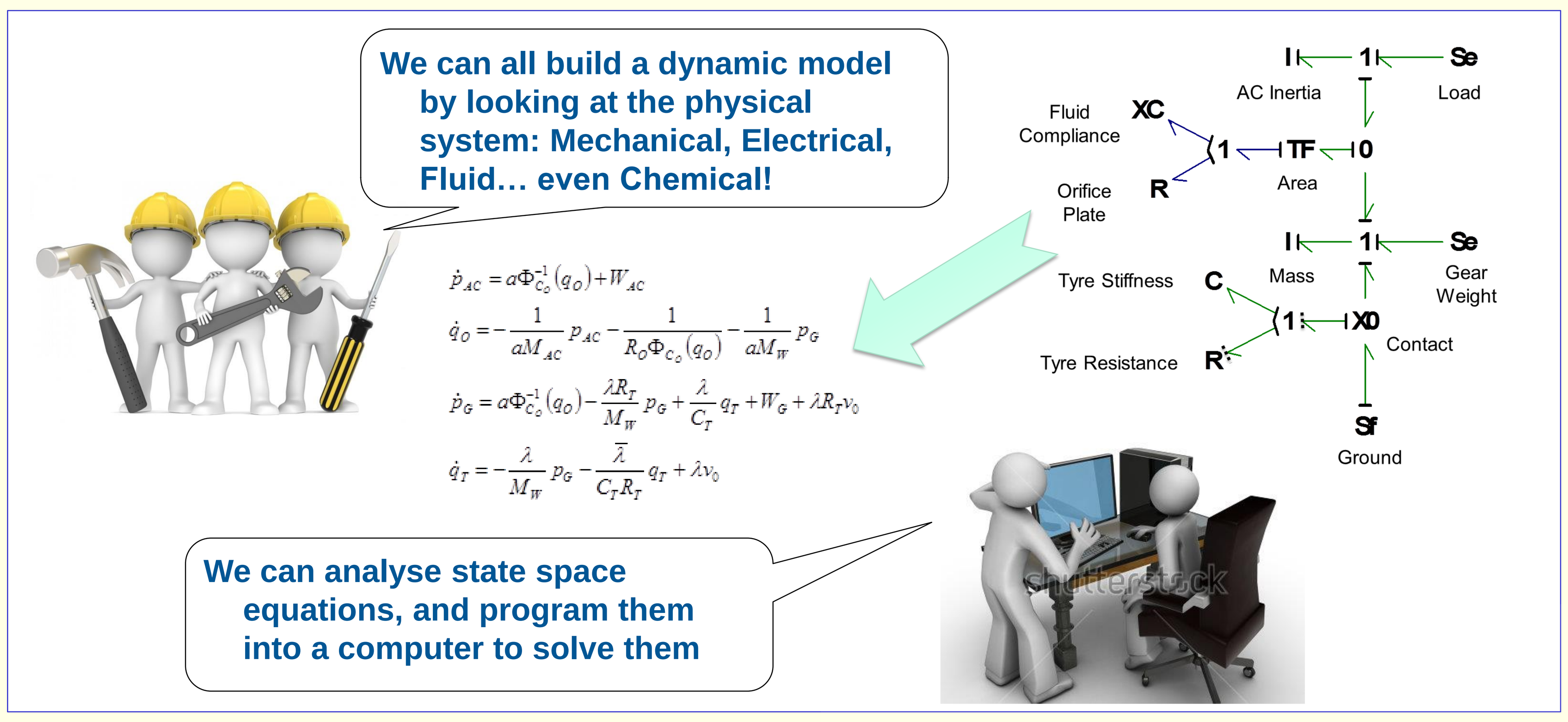

Fig. 1: Bond graphs are constructed by engineers, and then used to generate state space equations which can be computed easily.

Models for Automotive Design

Cars are typically designed using standard models and criteria (such as the "Olley Criteria" [1]) which are well-documented. They tend to be conservative, since they don't take account of complex dynamic behaviour such as nonlinearity, transient manoeuvres, and model coupling. However, they form a starting point to compare vehicles. For this project, 'quarter-car' and 'bicycle' models were constructed using bond graphs, to optimise suspension and model steady-state cornering respectively (Fig. 2). Rollover coefficient was also calculated. The results were then verified against a simulation in IPG CarMaker, a virtual prototyping software package.

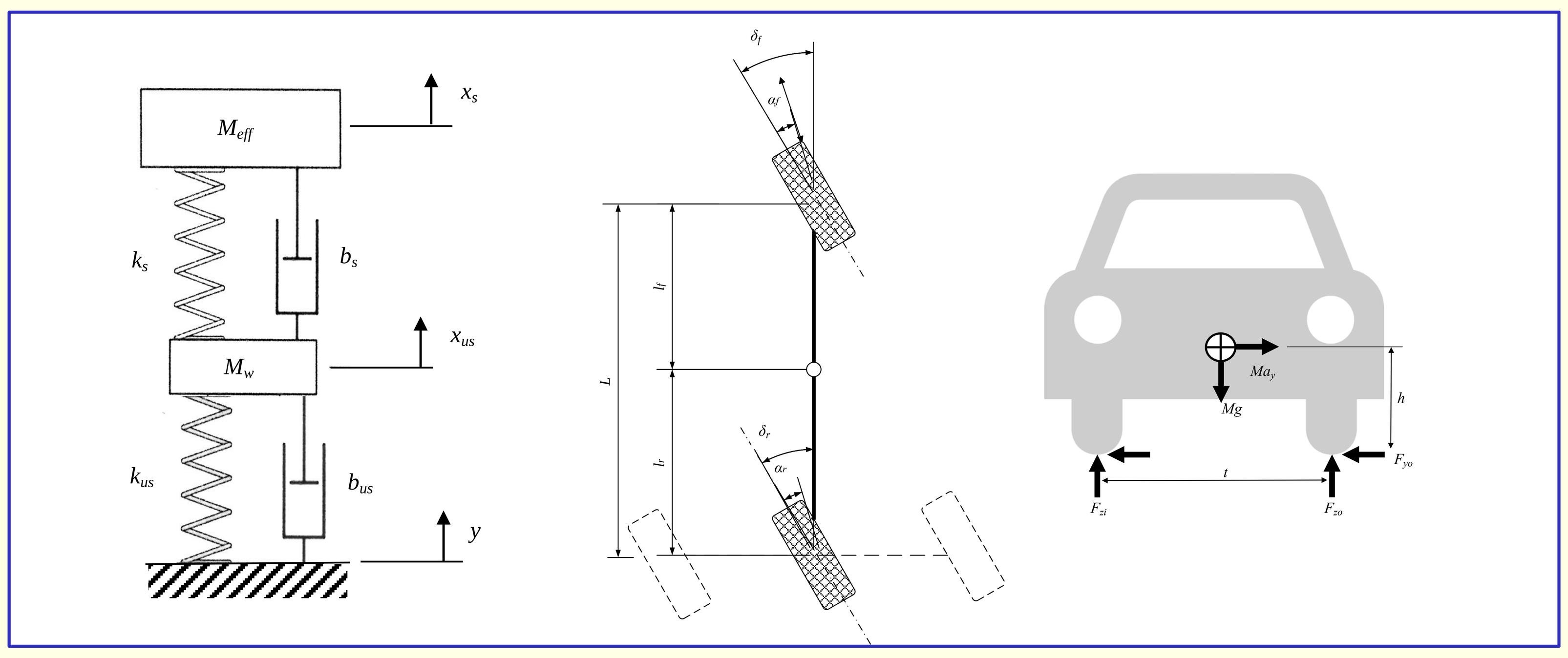

Fig. 2: Generic models: the 'quarter car' abstraction for ride dynamics [left], the 'bicycle' model for steady-state cornering [centre] and the quasi-static rollover model for roll coefficient [right].

Biography

Dr. Rebecca Margetts is a Senior Lecturer & Programme Leader at the University of Lincoln School of Engineering. She has a background in the automotive and aerospace industries, and is a Chartered Engineer. Her research centres around modelling and control of systems, particularly hybrid (nonsmooth dynamical) systems using Bond Graphs. She is an active member of the bond graph community and has contributed to a textbook on the subject.

APPLICATION

The Mibrid Mayfly

The Mayfly is a three-wheeled sports car (fig. 3) -- currently in the concept stage -- intended to be lightweight and perform well in the rural and semi-rural roads of Britain [2]. It has a 'delta' configuration i.e. one wheel at the front and two at the rear, and is driven by three hub motors (one in each wheel).

Results

Fig. 3: Rendering of the Mayfly concept

The suspension was successfully optimised to give a 'sporty' ride, and the vehicle can be seen to understeer whilst being more responsive than existing three-wheeled vehicles (fig. 4). The rollover threshold also compared favourably to other three-wheeled vehicles, due to the lower weight distribution. However, these calculations are not intended for a three-wheeled vehicle with all-wheel-drive, and did not capture a diagonal rolling motion seen in transient cornering during simulation. The model therefore needs more work in order to fully understand this behaviour.

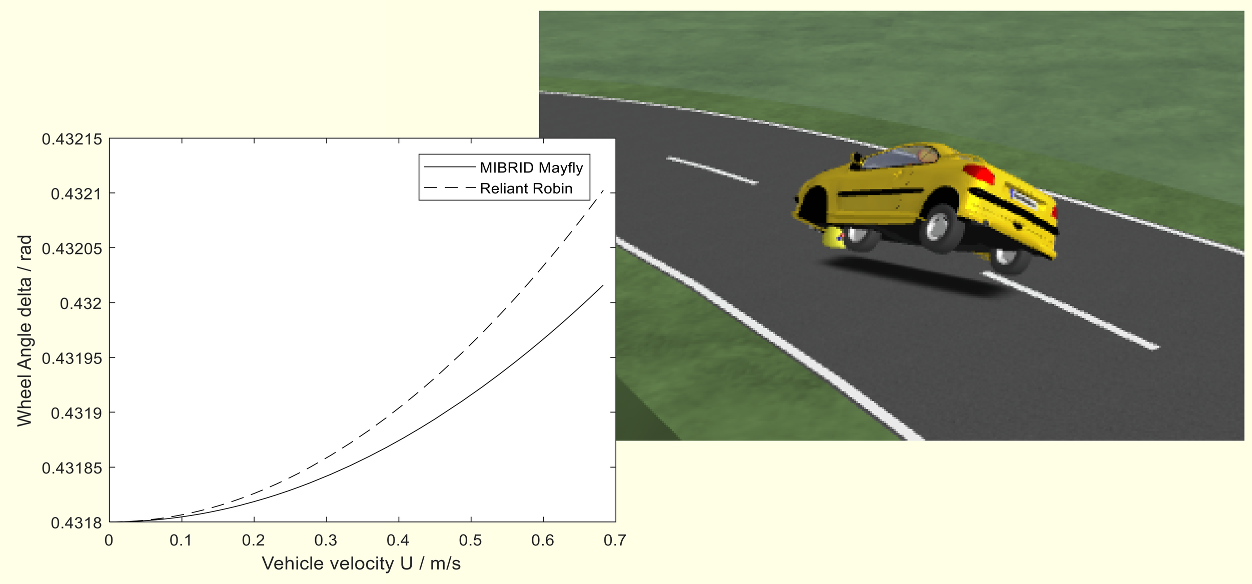

Fig. 4: Steady-State Cornering [left] and simulation of transient cornering will vehicle rolling [right].

Fig. 6: The Mibrid Cubbie

A significant output from this pilot study was the growth of a 'cluster' of partners looking at Electric Vehicles (fig. 5), and the stimulation of further research. An ERASMUS+ student from Sigma-Clermont (France) is currently working on the model, Mibrid have generously donated a Cubbie (fig. 6) to the School of Engineering for use in MEng Group Projects to develop an autonomous vehicle, and the team intend to apply for KTP funding to further the design.

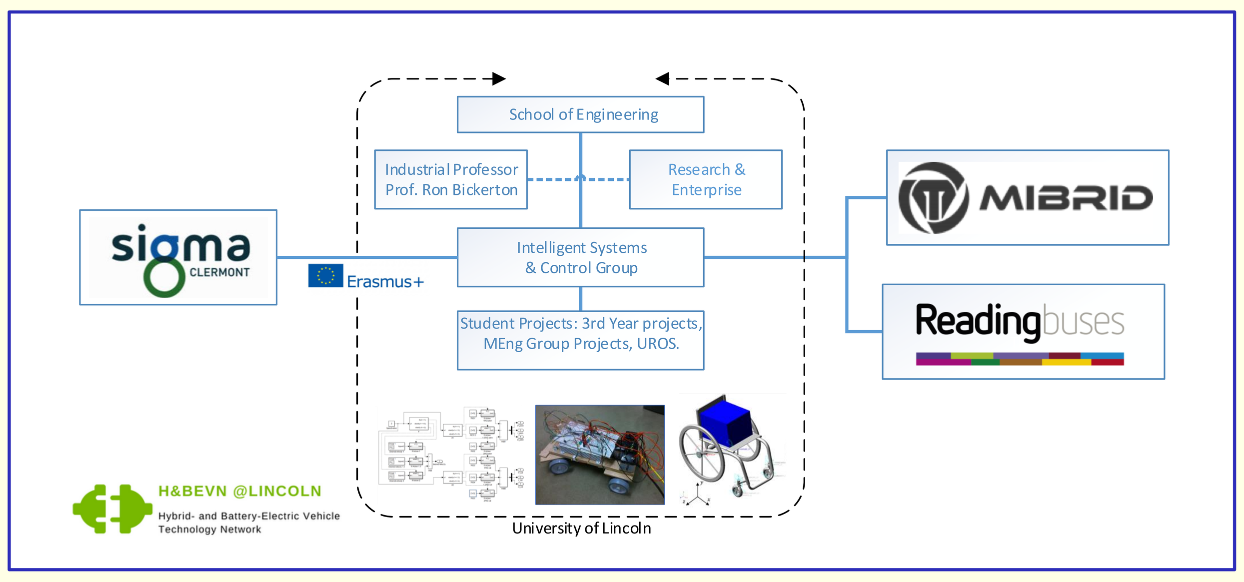

Fig. 5: The emerging Hybrid- and Battery-Electric Vehicle Technology Network

References

[1] T. D. Gillespie, *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, Inc., 1992.

[2] "Mayfly Prototype - Mibrid Ltd," 2017. [Online] Available: https://www.mibrid.com/mayfly/.

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